United States
Department of
Agriculture

Soil
Conservation
Service

Hydrology Training Series

Module 206 B - Peak Discharge (Graphical Method, TR-55)

Study Guide

Engineering
Hydrology Training Series
Module 206B

Peak Discharge

Graphical Method, TR–55

National Employee Development Section
Soil Conservation Service
United States Department of Agriculture
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Preface

This module consists of a study guide which contains a step by step process for calculating peak discharge from rural or urban areas using the TR-55 graphical method. This procedure is found in Chapter 4 of Technical Release 55, Urban Hydrology for Small Watersheds (TR-55).

Proceed through this module at your own pace. Be sure you completely understand each section before moving on. If you have questions or need help, please request assistance from your supervisor. If your supervisor cannot clear up your problems, he/she will contact the state appointed resource person. The resource person is familiar with the material and should be able to answer any questions you may have.

Be sure to write out your answers to the included activities. This will help to reinforce your learning. After completing each activity, compare your answers with the included solution.

Acknowledgment

The design and development of this engineering module is the result of a concerted effort by practicing engineers in the Soil Conservation Service. The contributions from many technical and procedural reviews have helped make this module one that will provide needed knowledge of hydrology/hydraulic skills to SCS employees.

Module Description

Objectives

Upon completion of this module the participant will be able to compute peak discharge using TR-55, Chapter 4, Graphical Peak Discharge Method.

Upon completion, the participant should be able to perform at ASK level 3 (Perform with Supervision).

Prerequisites

Modules 101-Introduction to Hydrology; 102-Precipitation; 103-Runoff Concepts; 104-Runoff Curve Number Computations, and 206A-Time of Concentration.

Time

Participant should take as long as necessary to complete the module. Training time for the module is approximately two hours.

Who May Take The Module

All Area-level engineers and technicians and others who compute peak discharge from areas greater than 2000 acres and from urban watersheds.

Method of Completion

This module is self-study, but the states or NTC should select a resource person to answer any questions the participant's supervisor cannot handle.

Content

This module presents the peak discharge equation, input requirements, peak discharge computations, and limitations.

Contents

Introduction

This training module presents the Graphical Peak Discharge method for computing peak discharge from rural and urban areas. The procedure is found in Chapter 4 of Technical Release 55, "Urban Hydrology for Small Watersheds" (TR-55).

The peak flow procedure in Module 106-Peak Discharge, which is based on Chapter 2 (1988 Version or later), EFM, is limited to small rural watersheds with drainage areas less than 2000 acres. The Graphical method in TR-55 was developed for urban watersheds, but can also be used for rural watersheds with drainage areas greater than 2000 acres. It can also be used for smaller rural watersheds if a time of concentration (T_c) computation has been made using the velocity procedure in Module 206A - Time of Concentration.

Graphical Peak Discharge Method

The Graphical Method was developed from hydrograph analysis using TR-20, "Computer Program for Project Formulation - Hydrology." The peak discharge equation is:

$$q_p = q_u A_m Q F_p$$

where

q_p = peak discharge, cfs

q_u = unit peak discharge, csm/in or cfs/mi{ per volume of runoff

A_m = drainage area, mi^2

F_p = pond and swamp adjustment factor

Input Requirements

The input requirements for the Graphical method are similar to those needed for the Chapter 2, EFM procedure for calculating peak flow. They are:

1. Drainage area, mi^2.
2. Runoff curve number (CN), obtained by using procedure in Module 104 Runoff Curve Numbers Computations.
3. Time of concentration (T_c), hr, obtained by using the procedurein Module 206A-Time of Concentration.
4. Appropriate rainfall distribution, Type I, IA, II or III.

5. 24-hour rainfall, in, for the desired frequency.

6. F_p, an adjustment for pond and swamp areas if the ponds and swamps are spread throughout the watershed and are not considered in the T_c computation.

Procedure

The general steps in computing the peak discharge using the Graphical method are:

1. For the watershed location selected, the appropriate rainfall distribution from Figure B-2 is found.

2. For a selected rainfall frequency, the 24-hour rainfall amount (P) is found, using Figure B-4 or a more detailed local precipitation map.

3. The CN is computed using procedures in Module 104. The CN and P are used to obtain the total runoff (Q).

4. Using the CN, an initial abstraction (I_a) is obtained from Table 4-1. An I_a/P ratio is then computed.

5. Exhibit 4 contains four graphs for the Types I, IA, II, and III rainfall distributions. For a T_c and I_a/P ratio, q_u is read. If the computed I_a/P ratio is outside the range shown on the graph, use the limiting value. If the ratio falls between the limiting values, use linear interpolation.

6. If a pond and swamp adjustment factor is needed, use Table 4-2.

All figures and tables mentioned above are found in TR-55. The ones needed to complete this module are found in Appendix A.

Limitations

The following limitations should be kept in mind when using the Graphical method for computing peak discharge:

1. The Graphical method provides a determination of peak discharge only. If a hydrograph is needed or watershed subdivision is required, use the Tabular Hydrograph method (Chapter 5, TR-55). Use TR-20 if the watershed is complex or a higher degree of accuracy is required.

2. The watershed must be hydrologically homogeneous, that is, described by a single weighted CN. A watershed that is 50% urban on A soils and 50% woods on D soils should be treated as two subwatersheds. However, a watershed that is 50% fallow on

C Soils and 50% small grain on B soils can be treated as a single homogeneous watershed, as an area weighted CN can be computed. Land use, soils, and cover are distributed uniformly throughout the watershed.

3. The watershed may have only one main stream or, if more than one, the branches off the main stream must have nearly equal T_c's.

4. The method cannot perform valley or reservoir routing.

5. The F_p factor can be applied only for ponds or swamps that are not in the T_c flow path.

6. The accuracy of peak discharge estimated by this method will be reduced if I_a/P values are used that are outside the range given Exhibit 4. In this case, the limiting I_a/P values are recommended for use.

7. This method should be used only if the CN is greater than 40.

8. When this method is used to develop estimates of peak discharge for both present and developed conditions of a watershed, use the same procedure when estimating T_c for each condition.

9. T_c values used with this method may range from 0.1 to 10 hours.

Activity 1

At this time, complete Activity 1 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers with the solution provided. When you are satisfied that you understand the material, continue with the Study Guide text.

Activity 1

1. When can the graphical peak discharge method be used?

2. What are the six input requirements in the Graphical Peak Discharge Method?

   a.

   b.

   c.

   d.

   e.

   f.

Activity 1 - Solution

1. When can the graphical peak discharge method be used?

   The graphical peak discharge method can be used for (1) Urban watersheds, (2) rural watersheds with drainage areas greater than 2000 acres, and (3) rural watersheds of less than 2000 acres with a computed T_c.

2. What are the six input requirements in the Graphical Peak Discharge Method?

   a. Drainage area

   b. Runoff curve number

   c. T_c

   d. Rainfall distribution type

   e. 24-hour rainfall for the desired frequency

   f. F_p, pond and swamp adjustment factor, if appropriate

Graphical Method Example

Given:

Project Name = Heavenly Acres

Drainage Area = 250 ac

Location = Dyer County, Tennessee

CN = 75

T_c = 1.5 hr

Rainfall Distribution = Type II

P25 = 6.0 in

Find:

The 25-year peak discharge using Worksheet 4 on the next page. This worksheet is from TR-55.

Solution:

When you have completed the worksheet, compare your solution with that found on the page after your worksheet. If you had trouble, review the Graphical method again.

Worksheet 4 – Graphical Peak Discharge Method

Project _____ By _____ Date _____

Location _____ Checked _____ Date _____

Circle one: Present Developed _____

1. Data:

Drainage area ..... A_m = _____ mi^2 (acres/640

Runoff curve number ..... CN = _____ (from worksheet 2)

Time of concentration ..... T_c = _____ hr (from worksheet 3)

Rainfall distribution type ..... = _____ (I, Ia, II, III)

Pond and swamp areas spread throughout watershed ..... = _____ Percent of A_m (_____ acres or Mi^2 covered)

		Storm #1	Storm #2	Storm #3
2.	Frequency ..... yr			
3.	Rainfall ..... in			
4.	Initial abstraction, Ia ..... in (Use CN with table 4–1)			
5.	Compute I_a/p			
6.	Unit peak discharge, qu ..... csm/in (Use T_c and I_a/P with exhibit 4–_____)			
7.	Runoff, Q ..... in (from worksheet 2).			
8	Pond and swamp adjustment factor, F_p ..... (Use percent pond and swamp area with table 4–2. Factor is 1.0 for .. zero percent pond and swamp area.)			
9.	Peak discharge, q_p ..... cfs (where $q_p = q_u A_m Q F_p$)			

Source: 210-VI-TR-55, Second edition, June 1986

Worksheet 4 – Graphical Peak Discharge Method

Project Heavenly Acres By RHM Date 10/15/85

Location Dyer County, Tennessee Checked UM Date 10/17/85

Circle one: (Present) Developed

1. Data:

Drainage area	A_m =	0.39	mi^2 (acres/640
Runoff curve number	CN =	75	(from worksheet 2)
Time of concentration	T_c =	1.53	hr (from worksheet 3)
Rainfall distribution type	=	II	(I, Ia, II, III)
Pond and swamp areas spread throughout watershed	=	—	Percent of A_m (— acres or Mi^2 covered)

		Storm #1	Storm #2	Storm #3
2.	Frequency ..... yr	25		
3.	Rainfall ..... in	6.0		
4.	Initial abstraction, Ia ..... in (Use CN with table 4–1)	0.667		
5.	Compute I_a/p	0.11		
6.	Unit peak discharge, qu ..... csm/in (Use T_c and I_a/P with exhibit 4– II)	270		
7.	Runoff, Q ..... in (from worksheet 2).	3.28		
8	Pond and swamp adjustment factor, F_p ..... (Use percent pond and swamp area with table 4–2. Factor is 1.0 for .. zero percent pond and swamp area.)	1.0		
9.	Peak discharge, q_p ..... cfs (where $q_p = q_u A_m Q F_p$)	345		

Source: 210-VI-TR-55, Second edition, June 1986

Activity 2

At this time, complete Activity 2 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers with the solution provided. When you are satisfied that you understand the material, continue with the Study Guide text.

Activity 2

Given:

Project = Joe's Problem

Drainage Area = 0.6 mi^2

Location = NW corner of Alabama

CN = 80

T_c = 1.8 hr

Rainfall Distribution = II

P50 = 7.0 in

Find:

The 50-year peak discharge using Worksheet 4 on the next page.

Solution:

Worksheet 4 – Graphical Peak Discharge Method

Project _____ By _____ Date _____

Location _____ Checked _____ Date _____

Circle one: Present Developed _____

1. Data:

Drainage area ..... A_m = _____ mi^2 (acres/640

Runoff curve number ..... CN = _____ (from worksheet 2)

Time of concentration ..... T_c = _____ hr (from worksheet 3)

Rainfall distribution type ..... = _____ (I, Ia, II, III)

Pond and swamp areas spread throughout watershed ..... = _____ Percent of A_m (_____ acres or Mi^2 covered)

		Storm #1	Storm #2	Storm #3
2.	Frequency ..... yr			
3.	Rainfall ..... in			
4.	Initial abstraction, Ia ..... in (Use CN with table 4–1)			
5.	Compute I_a/p			
6.	Unit peak discharge, qu ..... csm/in (Use T_c and I_a/P with exhibit 4–_____)			
7.	Runoff, Q ..... in (from worksheet 2).			
8	Pond and swamp adjustment factor, F_p ..... (Use percent pond and swamp area with table 4–2. Factor is 1.0 for .. zero percent pond and swamp area.)			
9.	Peak discharge, q_p ..... cfs (where $q_p = q_u A_m Q F_p$)			

Source: 210-VI-TR-55, Second edition, June 1986

Worksheet 4 – Graphical Peak Discharge Method

Project Joe's Problem By DEW Date 3/88

Location NW Corner of Alabama Checked UM Date 8/88

Circle one: (Present) Developed _____

1. Data:

Drainage area ..... A_m = 0.6 mi² (acres/640

Runoff curve number ..... CN = 80 (from worksheet 2)

Time of concentration ..... T_c = 1.8 hr (from worksheet 3)

Rainfall distribution type ..... = II (I, Ia, II, III)

Pond and swamp areas spread throughout watershed ..... = — Percent of A_m (— acres or Mi² covered)

		Storm #1	Storm #2	Storm #3
2.	Frequency ..... yr	50		
3.	Rainfall ..... in	7.0		
4.	Initial abstraction, Ia ..... in (Use CN with table 4–1)	0.5		
5.	Compute I_a/p	.1		
6.	Unit peak discharge, qu ..... csm/in (Use T_c and I_a/P with exhibit 4– II)	245		
7.	Runoff, Q ..... in (from worksheet 2).	4.69		
8	Pond and swamp adjustment factor, F_p ..... (Use percent pond and swamp area with table 4–2. Factor is 1.0 for .. zero percent pond and swamp area.)	1.0		
9.	Peak discharge, q_p ..... cfs (where $q_p = q_u A_m Q F_p$)	689		

Source: 210-VI-TR-55, Second edition, June 1986

Activity 3

At this time, complete Activity 3 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers with the solution provided. When you are satisfied that you understand the material, continue with the Study Guide text.

Activity 3

Given:

Project Name = Don's Farm

Drainage Area = 1.0 mi^2

Location = Calvert County, MD

CN = 85

T_c = 1.0 hr

Rainfall Distribution = II

P_{50} = 6.7 in

Find:

The 100-year peak discharge using Worksheet 4 on the next page. Assume 5% of the area is swampy, and the swampy areas are not along the flow path.

Solution:

Worksheet 4 – Graphical Peak Discharge Method

Project _____ By _____ Date _____

Location _____ Checked _____ Date _____

Circle one: Present Developed _____

1. Data:

Drainage area ..... A_m = _____ mi^2 (acres/640

Runoff curve number ..... CN = _____ (from worksheet 2)

Time of concentration ..... T_c = _____ hr (from worksheet 3)

Rainfall distribution type ..... = _____ (I, Ia, II, III)

Pond and swamp areas spread throughout watershed ..... = _____ Percent of A_m (_____ acres or Mi^2 covered)

		Storm #1	Storm #2	Storm #3
2.	Frequency ..... yr			
3.	Rainfall ..... in			
4.	Initial abstraction, Ia ..... in (Use CN with table 4–1)			
5.	Compute I_a/p			
6.	Unit peak discharge, qu ..... csm/in (Use T_c and I_a/P with exhibit 4–_____)			
7.	Runoff, Q ..... in (from worksheet 2).			
8	Pond and swamp adjustment factor, F_p ..... (Use percent pond and swamp area with table 4–2. Factor is 1.0 for .. zero percent pond and swamp area.)			
9.	Peak discharge, q_p ..... cfs (where $q_p = q_u A_m Q F_p$)			

Source: 210-VI-TR-55, Second edition, June 1986

Worksheet 4 – Graphical Peak Discharge Method

Project Don's Farm By DEW Date 8/88

Location Calvert County MD Checked MH Date 8/88

Circle one: (Present) Developed

1. Data:

Drainage area ..... A_m =	1.0	mi^2 (acres/640	
Runoff curve number ..... CN =	85	(from worksheet 2)	
Time of concentration ..... T_c =	1.0	hr (from worksheet 3)	
Rainfall distribution type ..... =	II	(I, Ia, II, III)	
Pond and swamp areas spread throughout watershed ..... =	5%	Percent of A_m (— acres or Mi^2 covered)	

		Storm #1	Storm #2	Storm #3
2.	Frequency ..... yr	50		
3.	Rainfall ..... in	6.7		
4.	Initial abstraction, Ia ..... in (Use CN with table 4–1)	0.353		
5.	Compute I_a/p	0.05		
6.	Unit peak discharge, qu ..... csm/in (Use T_c and I_a/P with exhibit 4– II)	357		
7.	Runoff, Q ..... in (from worksheet 2).	4.97		
8	Pond and swamp adjustment factor, F_p ..... (Use percent pond and swamp area with table 4–2. Factor is 1.0 for .. zero percent pond and swamp area.)	0.72		
9.	Peak discharge, q_p ..... cfs (where $q_p = q_u A_m Q F_p$)	1277		

Source: 210-VI-TR-55, Second edition, June 1986

Summary

In summary, you have learned how to use the TR-55 Graphical Method to Compute peak discharges.

Remember that there are certain limitations to using the Graphical Method. Do not abuse these limitations or your results may be in error.

Retain this Study Guide as a reference until you are satisfied that you have successfully mastered all the methods covered. It will provide an easy review at any time if you should encounter a problem.

If you have had problems understanding the module or if you would like to take additional, related modules, contact your supervisor.

When you are satisfied that you have completed this module, remove the Certification of Completion sheet (last page of the Study Guide), fill it out, and give it to your supervisor to submit, through channels, to your State or NTC Training Officer.

Appendix A

Charts and Tables

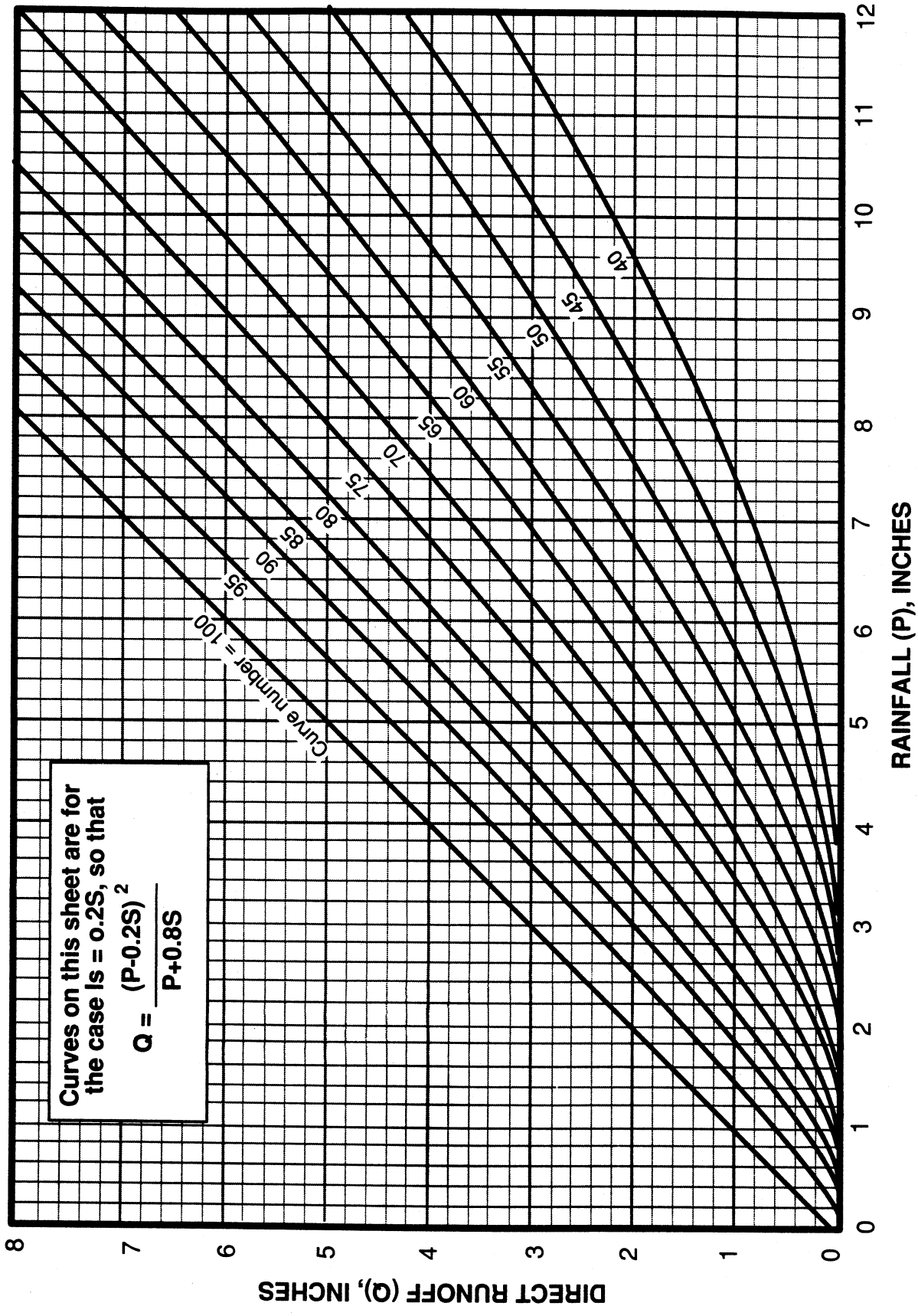

Figure 2-1. *Solution of runoff equation*
Source: Technical Release 55 (TR-55) Second Edition June 1986

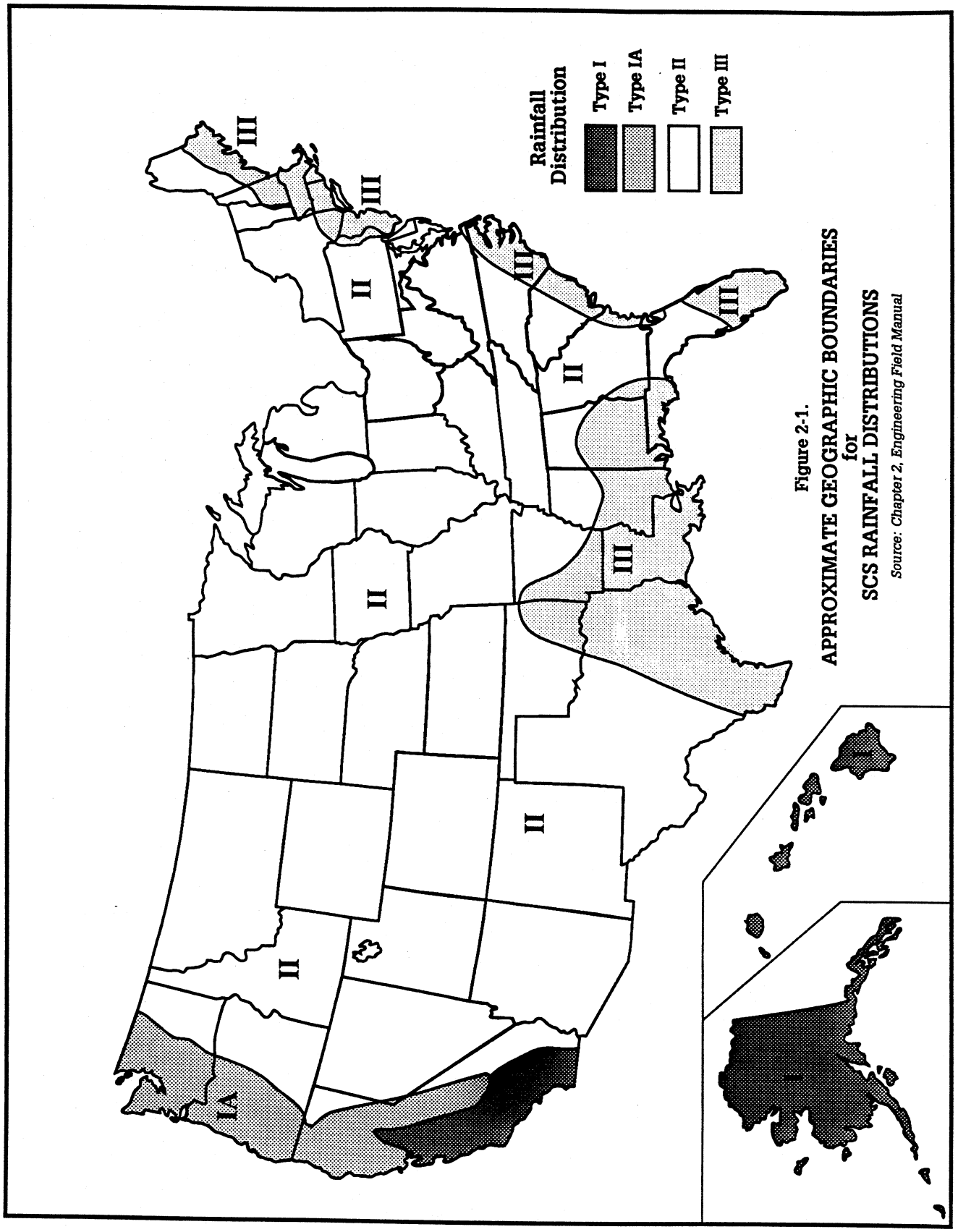

Figure 2-1.
APPROXIMATE GEOGRAPHIC BOUNDARIES for SCS RAINFALL DISTRIBUTIONS
Source: Chapter 2, Engineering Field Manual

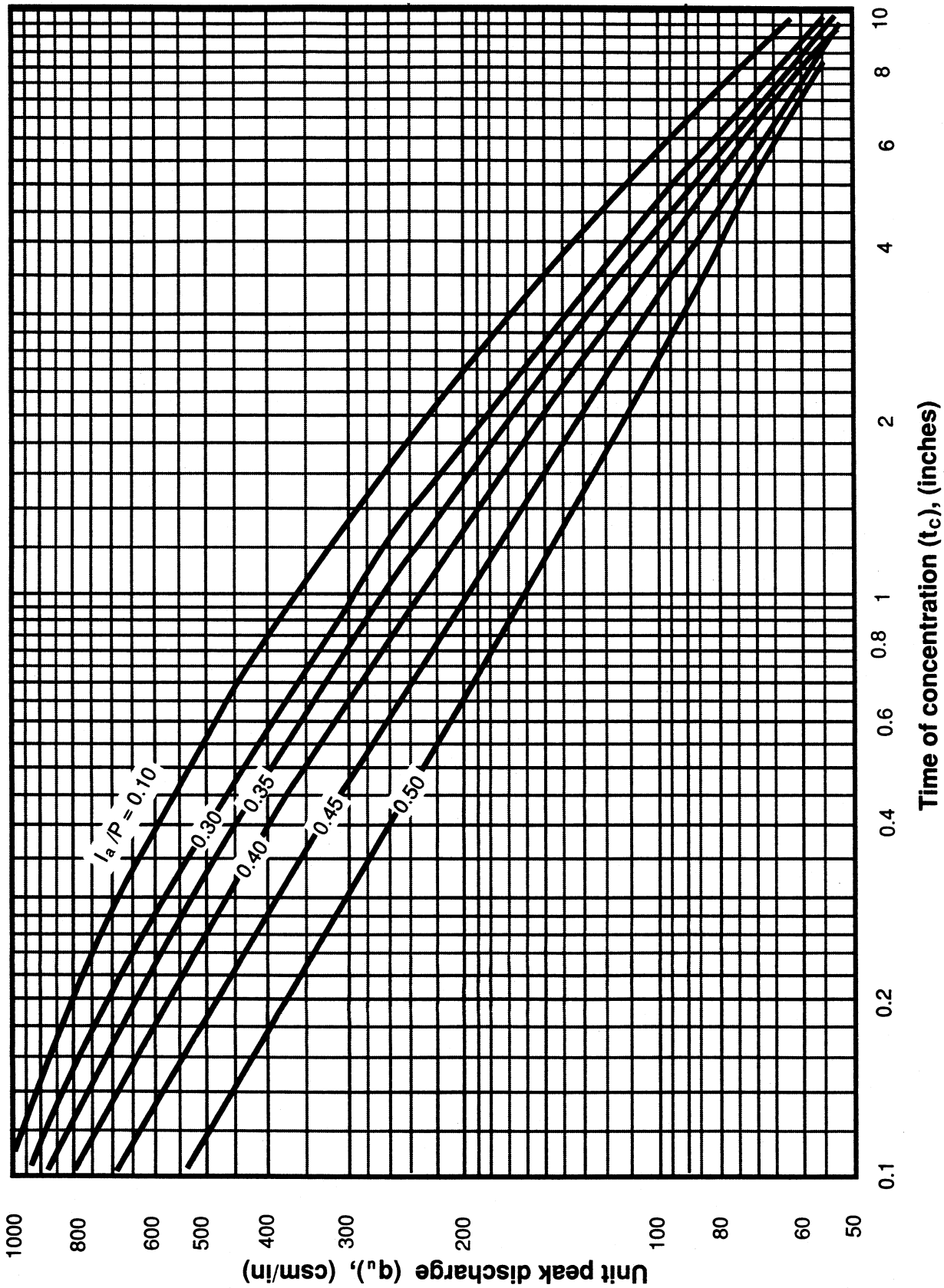

Exhibit 4-II. Unit peak discharge (qu) for SCS type II rainfall distribution

Table 4-1. *I_a values for runoff curve numbers.*

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.992	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

Table 4-2. *Adjustment factor (F_p) for pond and swamp areas that are spread throughout the watershed.*

Percentage of pond and swamp areas	F_p
0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

Hydrology Training Series
Module 206B
Peak Discharge
Graphical Method, TR-55

CERTIFICATION OF COMPLETION

This is to certify that

_____

completed Hydrology Training Series Module 206B
Peak Discharge (Graphical Method, TR55)

on _____ and should be credited with 2 hours of training.
Date

Signed _____ _____
Supervisor/Trainer Participant

Completion of Hydrology Training Series Module 206B
Peak Discharge (Graphical Method, TR-55),
is acknowledged and documented in the above-named employee's record.

Signed _____ _____
Training Officer Date